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NAVAL RESEARCH LABORATORY
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Naval Research Laboratory - Office of Naval Research

Materials Science and Technology

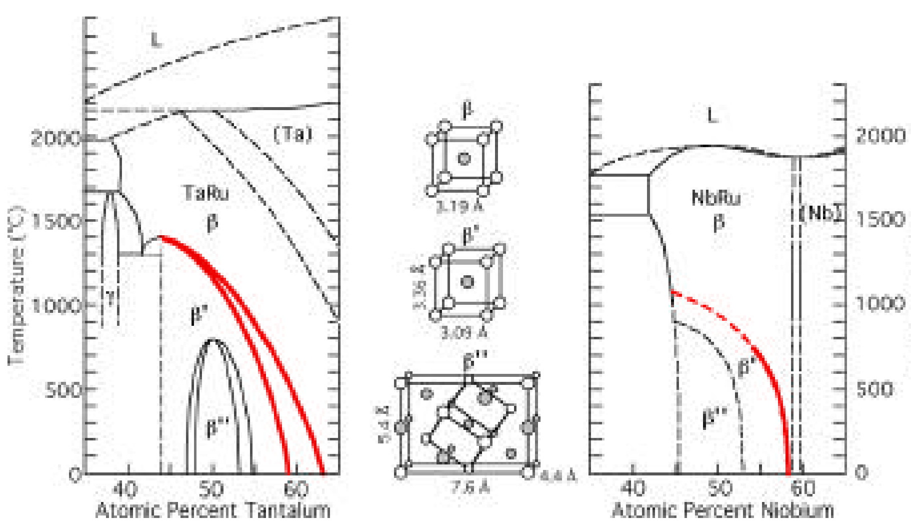
http://mstd.nrl.navy.mil

Science and Technology Success Stories

New High-Temperature Shape Memory Alloys

Shape memory alloys can be bent, compressed, or deformed in many other ways, but can then be made to recover their original shape by heating. Shape memory alloys have found many applications in the medical and fastener industries, but many potential high-temperature applications require a higher transition temperature than is commercially available. Currently, there are only a few experimental shape memory alloys known to have shape memory transition temperatures above 300 °C.

Scientists at the Naval Research Laboratory have recently discovered and patented a new class of shape memory alloys which exhibit the highest temperature shape memory effect yet observed. These new shape memory alloys are comprised of nearly equal amounts of ruthenium and either niobium (Nb-Ru) or tantalum (Ta-Ru). The shape memory transition temperatures of these alloys vary with composition from near room temperature up to 1100 °C for Nb-Ru and up to 1400 °C for Ta-Ru. Shape memory transition temperatures of the equiatomic alloys have been measured to be 885 °C for $Nb_{50}Ru_{50}$ and 1120 °C for $Ta_{50}Ru_{50}$, the highest shape memory transition temperature yet reported.



Partial phase diagrams of tantalum and ruthenium (left) and niobium and ruthenium (right), showing the composition and temperature ranges of the shape memory phase transitions (shown in red).

New High-Temperature Shape Memory Alloys

New Findings

- **Discovery of a new class of shape memory alloys**
  Comprising near equiatomic Nb-Ru and Ta-Ru alloys
- **Highest temperature shape memory alloy yet discovered**
  Shape memory transition temperatures of up to 1100 °C for Nb-Ru and up to 1400 °C for Ta-Ru
- **Significant strain recovery**
  Recovered strains of 4% to 5% measured at the tensile surface of bent samples
- **Shape accommodation microstructure**
  Coarse and fine twins with coherent boundaries between tetragonal variants
- **ß” has monoclinic crystallography**
  Low temperature phase (ß”) is not orthorhombic as previously reported
- **Low temperature microstructure**
  Fine structure of antiphase domains with some δ-domain boundaries

Potential Applications

The primary applications of these alloys would be as sensors, actuators, fasteners, and vibration dampeners that can operate in elevated temperature environments. Some potential high temperature environments where these alloys could be used are in or near aircraft or automobile engines and in the high-temperature chemical industry for process control.

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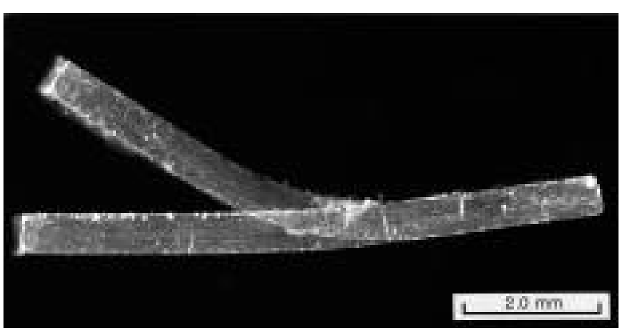
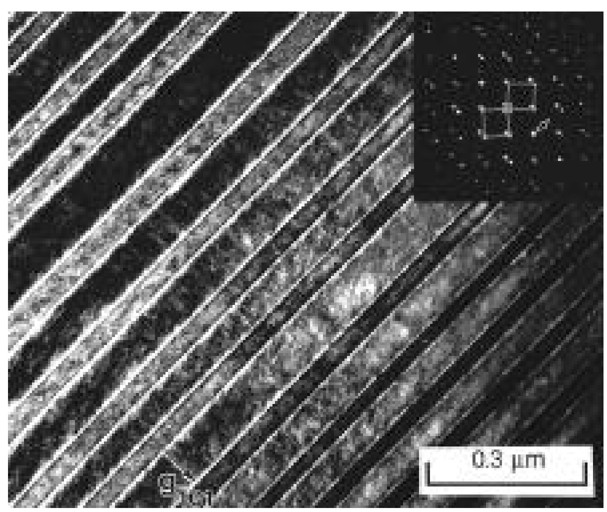


Demonstration of the Shape Memory Effect
Superimposed images of $Nb_{50}Ru_{50}$ before (bent) and after (straightened) being reheated to 1100 °C through the shape memory transformation



Highly Twinned Microstructure
Transmission electron microscope image and electron diffraction pattern of the fine twins formed by the shape memory transformation